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Estimates of Solar Variability Using the Solar Backscatter Ultraviolet (SBUV) 2 Mg II Index From the NOAA 9 Satellite

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The Mg II core to wing index was first developed for the Nimbus 7 solar backscatter ultraviolet (SBUV) instrument as an indicator of solar variability on both solar 27-day rotational and solar cycle time scales. This work extends the Mg II index to the NOAA 9 SBUV 2 instrument and shows that the variations in absolute value between Mg II index data sets caused by interinstrument differences do not affect the ability to track temporal variations. The NOAA 9 Mg II index accurately represents solar rotational modulation but contains more day to day noise than the Nimbus 7 Mg II index. Solar variability at other UV wavelengths is estimated by deriving scale factors between the Mg II index rotational variations and at those selected wavelengths. Because radiation near the Mg II line core originates at levels in the solar atmosphere comparable to those giving rise to the continuum near 200 nm, the Mg II index accurately tracks the flux in this photochemically important region. Based on the 27-day average of the NOAA 9 Mg II index and the NOAA 9 scale factors, the solar irradiance change from solar minimum in September 1986 to the beginning of the maximum of solar cycle 22 in 1989 is estimated to be 8.6% at 205 nm, 3.5% at 250 nm, and less than 1% beyond 300 nm.

INTRODUCTION

Solar ultraviolet radiation is a major driving force in the chemistry and dynamics of the Earth's atmosphere, particularly in the formation and destruction of ozone [e.g., *Brasseur and Solomon*, 1986]. Because ozone and oxygen are so effective in absorbing ultraviolet radiation before it reaches the Earth's surface, direct monitoring of solar UV irradiance must be done from above the atmosphere, requiring the use of rockets, Space Shuttle payloads, or satellites. Rocket measurements provide a "snapshot" of the solar irradiance at a specific time, with estimated absolute calibration errors of approximately 10%, and the disadvantage that subsequent flights are often separated by months or years [*Lean*, 1987, and references therein]. In rocket or Shuttle experiments the payload is returned to Earth after each flight, allowing the instrument to be recalibrated so that any necessary corrections for instrument sensitivity changes can be derived. Satellite instruments have the advantage of being able to make continuous observations over periods of months or years with absolute calibration errors of approximately 3–8%, allowing detailed tracking of long-term solar behavior. A major disadvantage of satellite observations is that instrument sensitivity tends to vary with time in space and exposure to solar radiation. Because satellite instruments do not return to Earth, in the absence of on-board calibration systems, characterization of instrument changes is difficult [e.g., *Cebula et al.*, 1988; *Herman et al.*, 1990; *Schlesinger and Cebula*, 1992]. Most instruments currently measuring solar ultraviolet irradiance are designed to minimize the impact of variations in sensitivity by monitoring one or more aspects of the changes in the instrument characterization [*VanHoosier et al.*, 1988; *Weiss et al.*, 1991].

The problems in determining solar activity variations from a given instrument can be minimized by using ratios of irradiances. A number of conditions can be established for a successful irradiance ratio: (1) the ratio should use a wavelength with significant solar activity in the numerator and a wavelength with little or no activity in the denominator so that solar variations can be uniquely identified; 2) the wavelengths used in the ratio should be closely spaced to minimize wavelength-dependent instrumental effects; and 3) the reference wavelengths should be equally spaced on both sides of the active wavelength to remove linear wavelength-dependent degradation effects, which dominant to a first approximation.

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The Mg II core to wing index, first developed by *Heath and Schlesinger* [1986] (hereafter *HS*) for the Nimbus 7 SBUV instrument, satisfies all of the above conditions. The index numerator is composed of the average of the irradiance at three consecutive wavelengths near 280 nm at the core of the Mg II *h* and *k* doublet, which is unresolved at the SBUV 1.1-nm band pass. The denominator of the ratio consists of irradiance values from two pairs of wavelengths approximately equidistant from the line core, which fall at relative maxima of the solar irradiance in the wings of the Mg II doublet. For the purposes of this paper these wing measurements are defined as the "local continuum," although there are weak solar lines present which prevent a true continuum from being observed. Because the full set of wavelengths for the ratio spans less than 7 nm (Table 1), any calibration drift can be closely approximated as linear with wavelength, which makes the Mg II index insensitive to instrument degradation.

The Mg II index results for Nimbus 7 SBUV were discussed extensively by *HS* and *Schlesinger and Heath* [1988]. They demonstrated that the Mg II index is capable of measuring solar rotational modulation on both 27- and 13.5-day time scales and solar cycle variability on an 11-year time scale. The measured decrease in the 27-day averaged Nimbus 7 Mg II index was approximately 8% from the peak of solar cycle 21 in 1979 to the minimum in 1986. Rotational modulation as large as 6% was observed during the solar cycle maximum in 1979–1980 [*Schlesinger et al.*, 1990].

TABLE 1. Mg II Index Wavelengths for Nimbus 7 SBUV and NOAA 9 SBUV 2

Position	Nimbus 7,* nm	NOAA 9, nm
Wing 1	276.54	276.54
Wing 2	276.74	276.69
Core 1	279.74	279.80
Core 2	279.94	279.94
Core 3	280.14	280.09
Wing 3	283.14	283.19
Wing 4	283.34	283.34

SBUV is solar backscatter ultraviolet.
*Based on the initial wavelength calibration given by *Schlesinger et al.* [1988].

MEASUREMENTS

The results presented in this paper are based on data from the SBUV 2 instrument on-board the NOAA 9 spacecraft, which is the first of the second-generation SBUV instruments. A description of this instrument and its initial characterization can be found in the work of *Frederick et al.* [1986]. The spacecraft was launched on December 12, 1984, into a nominally sun synchronous orbit and began taking regular solar measurements on March 14, 1985. The irradiance values used to construct the Mg II index in this paper are extracted from the daily averages of all continuous (sweep mode) scans, where normally two scans over the 160- to 400-nm region are taken each day. These irradiances have been normalized to a 1 AU Sun-Earth distance and corrected for changes in the instrument output due to variations of the solar vector with respect to the diffuser normal (goniometry), temperature dependence of the photomultiplier tube sensitivity, nonlinearity of the electronic gain, and changes in the ratios between the instrument's three electronic gain ranges that are wavelength and time dependent [*Cebula et al.*, 1990; *Cebula and DeLand*, 1992]. No corrections have been applied to the data for long-term instrument sensitivity changes. As previously discussed, the Mg II index is constructed to minimize sensitivity to long-term instrument change. Step scan (discrete mode) observations of the Mg II line, from which a separate Mg II index data set can be created, have also been made by NOAA 9 since May 1986 [*Donnelly*, 1988, 1990]. In this paper, only the NOAA 9 sweep mode Mg II index will be considered to allow direct comparisons with the Nimbus 7 Mg II index. Comparisons between the results presented here and the results of *Donnelly* [1990] are discussed by *DeLand and Cebula* [1992].

Because of the precession of the NOAA 9 spacecraft orbit, the equator crossing time of the orbit increased from approximately 1430 at launch to approximately 1730 by September 1988. During the period from September 1988 to the following April and each succeeding year the angle of sunlight onto the instrument diffuser plate is outside the range of the prelaunch calibration. Data analysis beyond September 1988 has been performed using the prelaunch goniometry, which introduces errors estimated to be as large as 7% in the derived irradiances between September 1989 and April 1990, when the most extreme solar incidence angles are observed. Wavelength-independent errors cancel out for the Mg II index irradiance ratio. A preliminary analysis of the goniometry errors during this period shows a wavelength dependence to the irradiance change of less than 0.1% over the Mg II index wavelength interval, which will not affect the results used in this paper. The shadow from the NOAA 9 spacecraft solar power array blocked all solar measurements for a 2-month period in late 1988, creating a gap in the data record.

The wavelength range used for the NOAA 9 Mg II index lies in the crossover region between two of the three electronic gain ranges used in the SBUV 2 instrument to record input signals over 5 orders of magnitude. The Mg II index core wavelengths have irradiance levels which fall in the upper end of gain range 2, giving a high signal to noise ratio and a very clean signal. However, the irradiance levels for the continuum wavelengths are large enough to fall in the lower end of gain range 3, where the average signal is 80–100 counts after subtracting the electronic offset. The standard deviation of this offset value is 4 counts [*Frederick et al.*, 1986; *Cebula et al.*, 1990], thus introducing an uncertainty of 4–5% into each observation. Averaging four wavelengths to create a continuum irradiance for the Mg II index reduces the noise level to approximately 2%. This uncertainty limits the precision with which the Mg II index can be derived from the SBUV 2 instrument. Increasing the number of wavelengths in the continuum average to 12 (six on each side of the Mg II line core) could reduce the noise to approximately 1.2% based on statistical considerations, assuming that the irradiance fluctuations are wavelength independent. However, this increased width also increases the possibility of sampling solar variations at lines which are not resolved by the SBUV 2 instrument, defeating the purpose of using a revised Mg II index formulation. An Mg II index constructed with 12 wavelengths averaged for the continuum irradiance showed no statistically significant differences from the formulation used herein.

NOAA 9 MG II INDEX RESULTS

The NOAA 9 Mg II index time series for March 1985 through September 1990 is shown in Figure 1. The figure shows a day-to-day noise in the Mg II index at the ±1% level, as discussed in the previous section. The noise level is dramatically reduced for a 2-month period in mid-1986. During this time the sweep mode measurements were made on every orbit (there are 13–14 orbits per day) instead of the nominal 1 orbit per day, leading to a reduction in the Mg II index statistical noise by a factor of 3–4. A rotational modulation of approximately 0.7% can be seen during this period of increased measurement frequency, demonstrating a significant noise reduction and showing that the NOAA 9 Mg II index is measuring solar rotational variability even at the minimum of the 11-year solar cycle.

Figure 2 shows the NOAA 9 Mg II index time series after smoothing the data with a 5-day-wide binomial function, with the 27-day running average of the index superimposed. The 27-day running average of the Mg II index increased by approximately 9% from the solar cycle 22 minimum in 1985–1986 through the solar cycle maximum period in 1989–1990. The duration of the period of solar minimum and the onset of increased solar activity shown here coincide with results from other indicators of solar activity, such as 10.7 cm radio flux and Lyman alpha irradiance at 121.6 nm [*Barth et al.*, 1990]. Although the solar activity level is low in 1985–1986 during the minimum between solar cycles 21 and 22, occasional periods of approximately 27-day rotational modulation with amplitudes of 1.0–1.5% in the binomially smoothed Mg II index and lasting 2–3 rotations can be seen.

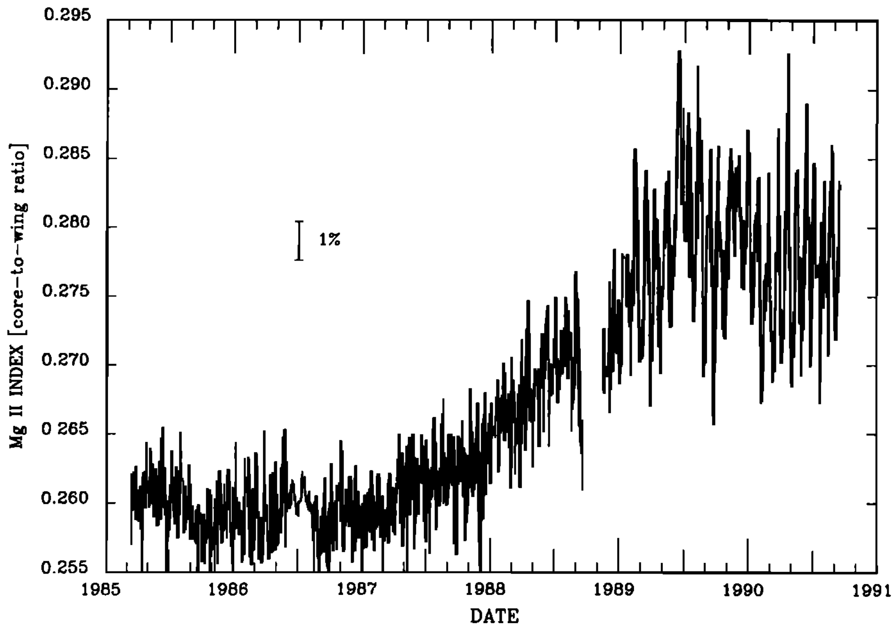

Fig. 1. Time series of NOAA 9 sweep mode Mg II index values computed from daily average irradiance measurements.

Because the data have been smoothed, the actual amplitude of these variations may be slightly different from the results shown. During 1987–1988 the 27-day periodicity becomes more visible, and the amplitude of the smoothed rotational modulation increased to 2–3%. A period of approximate 13.5-day modulation, indicating simultaneous strong active regions on opposing faces of the Sun [*Lean*, 1987], can be seen during early 1988. In 1989–1990 the baseline level of the Mg II index remained relatively constant, with smoothed rotational modulation amplitudes of 4–7% superimposed.

Ground-based indicators of solar ultraviolet activity have also been developed, utilizing chromospheric emissions such as the He I 1083-nm line [*Harvey*, 1984] and the Ca II K line at 393 nm [*White et al.*, 1990]. While either the equivalent width of the He I 1083-nm line, the Ca II K index, or the Mg II index may be used as an adequate representation of long-term solar ultraviolet variability, the superior data coverage of the NOAA 9 Mg II index makes it preferable for studies of short-term variations. For the time period considered in this paper (March 1985 to September 1990), the daily record of the NOAA 9 Mg II index is approximately 85% complete, with 5 gaps of 5 or more consecutive days. Over the same interval the He I 1083-nm data record is 60% complete, with more than 40 gaps of 5 or more days. Ca II K index measurements are made on 4 consecutive days each month, which does not permit studies of short-term variability.

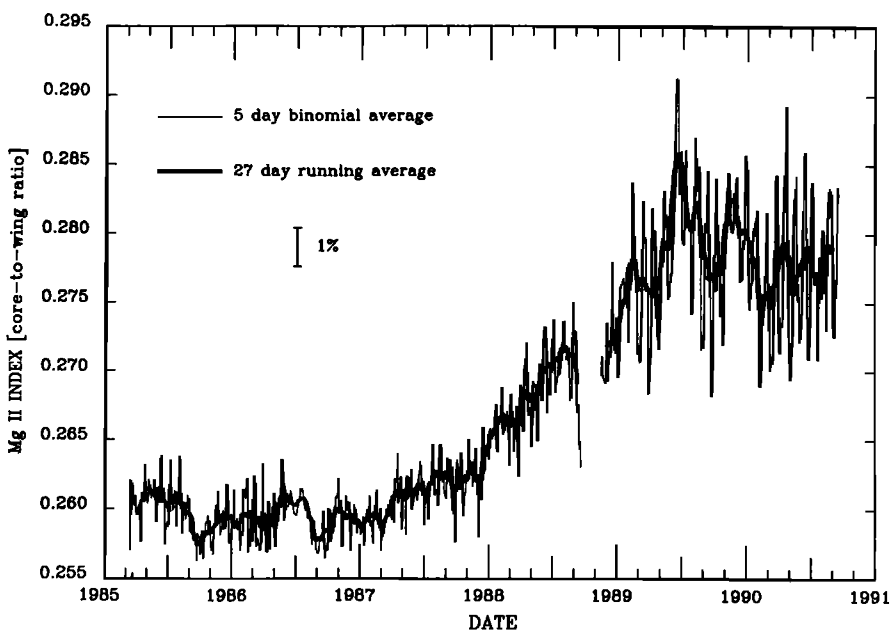

Fig. 2. The NOAA 9 Mg II index time series after smoothing with a 5-day binomial average. The 27-day running average of the Mg II index time series is superimposed as a thick solid line.

Table 2 lists the average NOAA 9 Mg II index value during each of the nominal 27-day solar rotational periods from March 1985 to September 1990. This averaging interval was chosen to try to ensure that all averages represented complete solar rotations, since a monthly average of 30–31 days might include two rotational maxima or minima. The 27-day average Mg II index values are constant to within 0.5% between March 1985 and December 1986, then increase by 9% from January 1987 through May 1989.

TABLE 2. NOAA 9 Mg II Index Averaged Over 27-day Intervals

Bartel Period	Start Date	Average Value
2072	March 14, 1985	0.2601
2073	April 10, 1985	0.2606
2074	May 7, 1985	0.2611
2075	June 3, 1985	0.2607
2076	June 30, 1985	0.2605
2077	July 27, 1985	0.2604
2078	Aug. 23, 1985	0.2595
2079	Sept. 19, 1985	0.2573
2080	Oct. 16, 1985	0.2583
2081	Nov. 12, 1985	0.2593
2082	Dec. 9, 1985	0.2592
2083	Jan. 5, 1986	0.2587
2084	Feb. 1, 1986	0.2596
2085	Feb. 28, 1986	0.2590
2086	March 27, 1986	0.2590
2087	April 23, 1986	0.2592
2088	May 20, 1986	0.2611
2089	June 16, 1986	0.2603
2090	July 13, 1986	0.2606
2091	Aug. 9, 1986	0.2581
2092	Sept. 5, 1986	0.2579
2093	Oct. 2, 1986	0.2594
2094	Oct. 29, 1986	0.2597
2095	Nov. 25, 1986	0.2594
2096	Dec. 22, 1986	0.2586
2097	Jan. 18, 1987	0.2594
2098	Feb. 14, 1987	0.2590
2099	March 13, 1987	0.2597
2100	April 9, 1987	0.2613
2101	May 6, 1987	0.2611
2102	June 2, 1987	0.2617
2103	June 29, 1987	0.2612
2104	July 26, 1987	0.2625
2105	Aug. 22, 1987	0.2623
2106	Sept. 18, 1987	0.2615
2107	Oct. 15, 1987	0.2623
2108	Nov. 11, 1987	0.2621
2109	Dec. 8, 1987	0.2637
2110	Jan. 4, 1988	0.2657
2111	Jan. 31, 1988	0.2668
2112	Feb. 27, 1988	0.2658
2113	March 25, 1988	0.2682
2114	April 21, 1988	0.2674
2115	May 18, 1988	0.2699
2116	June 14, 1988	0.2700
2117	July 11, 1988	0.2713
2118	Aug. 7, 1988	0.2712
2119	Sept. 3, 1988	0.2677
2120	Sept. 30, 1988	0.0000
2121	Oct. 27, 1988	0.2703
2122	Nov. 23, 1988	0.2719
2123	Dec. 20, 1988	0.2724
2124	Jan. 16, 1989	0.2763
2125	Feb. 12, 1989	0.2759
2126	March 11, 1989	0.2760
2127	April 7, 1989	0.2768
2128	May 4, 1989	0.2790
2129	May 31, 1989	0.2847
2130	June 27, 1989	0.2821
2131	July 24, 1989	0.2815
2132	Aug. 20, 1989	0.2780
2133	Sept. 16, 1989	0.2761
2134	Oct. 13, 1989	0.2786
2135	Nov. 9, 1989	0.2824
2136	Dec. 6, 1989	0.2803
2137	Jan. 2, 1990	0.2783
2138	Jan. 29, 1990	0.2740
2139	Feb. 25, 1990	0.2752
2140	March 24, 1990	0.2780
2141	April 20, 1990	0.2777
2142	May 17, 1990	0.2775
2143	June 13, 1990	0.2782
2144	July 10, 1990	0.2761
2145	Aug. 6, 1990	0.2792

Comparisons Between Nimbus 7 and NOAA 9

The wavelength scale of the Nimbus 7 SBUV instrument has a sampling interval of approximately 0.2 nm, while the NOAA 9 SBUV 2 wavelength scale has a step size of approximately 0.147 nm in the vicinity of the Mg II line. This difference means that while the central wavelength used for the Mg II line core is virtually identical in both instruments (Table 1), the effective width of the Mg II line core, as measured by the averaged irradiance from three consecutive wavelengths, and thus the absolute value of the Mg II index from each instrument are different. Figure 3 shows that the absolute value of the NOAA 9 Mg II index is approximately 2% lower than the Nimbus 7 Mg II index during the period of simultaneous observations from March 1985 to February 1987.

The difficulty in matching absolute Mg II index values between two different instruments was discussed by *Hall and Anderson* [1988], who nevertheless found reasonable agreement in the solar variability trend between Nimbus 7 Mg II index values and a set of Mg II index values derived from balloon data. The reproducibility of rotational modulation and long-term variations in the Mg II index between different instruments, as a representation of true solar variability, is more significant than agreement in absolute value. Given sufficient temporal overlap between Mg II index data sets, the bias in absolute values can be determined. Most of the rotational modulation features in the Nimbus 7 Mg II index time series in Figure 3 are reproduced in the NOAA 9 time series, both in location and in relative amplitude. Note again the noise in the NOAA 9 Mg II index. Employing a linear regression fit between the Nimbus 7 and the NOAA 9 Mg II indexes during the period of data overlap (March 1985 to February 1987), using data sets smoothed with a 5-day binomial average to reduce statistical noise, a correlation coefficient of $R = 0.643$ is found. This result is significantly affected by the day-to-day noise in the NOAA 9 Mg II index, since the peak-to-peak magnitude of the solar rotational modulation is approximately 1% at this time. For the period between June and August 1986, when the NOAA 9 solar irradiance measurement frequency was increased by a factor of 13, the linear regression correlation coefficient increases to $R = 0.870$. The NOAA 9 sweep mode Mg II index temporal variations shown in Figure 2 are consistent with the NOAA 9 discrete mode Mg II index results shown by *Donnelly* [1988, 1990].

Scale Factors for Other UV Wavelengths

The importance of solar variations at UV wavelengths to the dynamics of the middle atmosphere makes the development of a proxy indicator for these variations highly desirable. Because the NOAA 9 Mg II index values are derived from SBUV 2 solar irradiance measurements, simple multi-

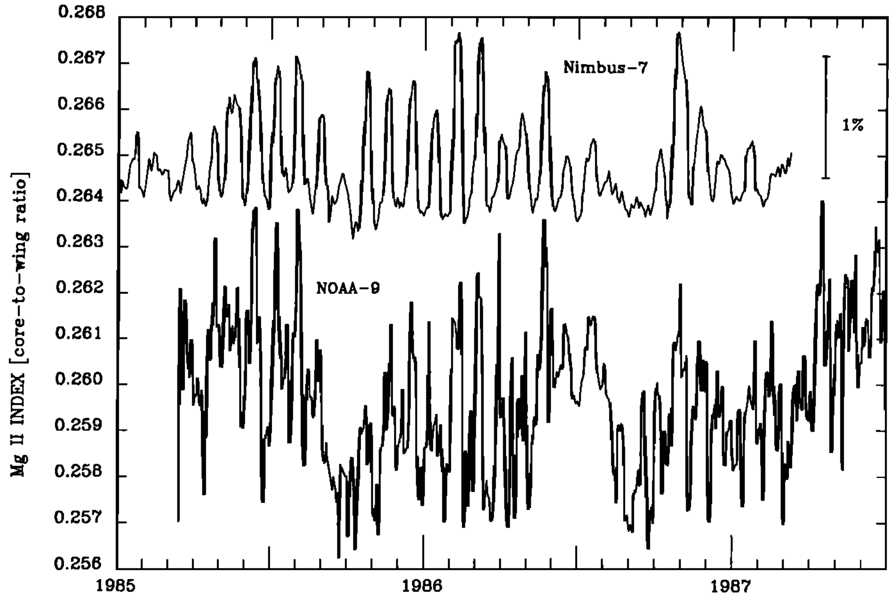

Fig. 3. The Nimbus 7 Mg II index (top curve) and NOAA 9 sweep mode Mg II index (bottom curve) time series between January 1985 and June 1987. Both time series have been smoothed with a 5-day binomial function.

plicative factors can be developed to relate the Mg II index variations to solar variations at other UV wavelengths without worrying about unknown instrument sensitivity changes or interinstrument differences. Such "scale factors" were presented by *HS* for Nimbus 7 at selected UV wavelengths. The differences in Mg II index values between SBUV instruments caused by the different wavelength scales means that scale factors must be derived independently for each instrument. However, the relative variations of the scale factors with wavelength should be similar.

The method used here follows that of *HS*, where the modulation strength of individual solar rotations is used to represent Mg II index variability. A set of seven solar rotations with significant amplitude modulation during 1989–1990 was selected from the NOAA 9 Mg II index time series for analysis. Mg II index values for three closely spaced (but not necessarily consecutive) days were chosen and averaged to represent the maximum value obtained by the Mg II index for each rotation. The minimum Mg II index value for the rotation was determined by averaging a total of 4 days, with 2 days selected on each side of the maximum to minimize any time-dependent changes in instrument sensitivity during the rotation. Possible effects due to reduced sensitivity over time as a result of instrument drift are minimized by treating each rotation as an independent point, so that only the relative wavelength dependence of changes over each 27-day interval are significant. The change in NOAA 9 SBUV/2 sensitivity during a 27-day period is estimated to be less than 0.3% shortward of 300 nm and less than 0.2% longward of 300 nm [*Cebula and DeLand,* 1992]. The ratio of the averaged maximum and minimum values then represents the strength of the Mg II index rotational modulation. This process was repeated for each SBUV 2 wavelength using the same observation dates to derive an irradiance rotational modulation strength. The ratio of the irradiance strength to the Mg II index strength defines a scale factor for a specific wavelength and time, which expresses irradiance variability as a function of Mg II index variability.

The scale factors relating Mg II index changes to irradiance variability at each wavelength are determined by taking the slope of the least squares fit line to the set of rotational modulation strengths for all rotations, where the Mg II index changes are the independent variable. An additional point is included in the sample data set at each wavelength to represent zero variability but is not a fixed constraint on the regression fit. The NOAA 9 Mg II index scale factors derived using this method are shown in Figure 4 with no wavelength smoothing. Scale factors below 170 nm have not been plotted in Figure 4 because the noise in the raw irradiance data caused by low signal levels prevents meaningful conclusions from being drawn. The predicted solar variability between 180 and 207 nm is comparable to or larger than the Mg II index variability, with a strong peak at the 181.6-nm Si II emission line. The Mg II index scale factors drop by a factor of 2 longward of the Al I ionization edge at 208 nm, then gradually decrease further over the 210- to 265-nm interval. Between 265 and 290 nm the solar irradiance measured by the SBUV 2 instrument passes through the electronic gain range transition discussed previously, creating significant statistical noise and increased uncertainty in the derived scale factors. The standard deviation of the linear regression fit is as large or larger than the magnitude of the derived scale factor for all wavelengths in this region, except those associated with strong lines such as Mg II at 280 nm and Mg I at 285 nm. Because of the increase in relative error we do not recommend the use of the scale factor values between 265 and 290 nm (again excepting the strong lines) for quantitative purposes. Beyond 290 nm the scale factors are approximately zero, in agreement with the estimate of solar irradiance change over a solar cycle being less than 1% longward of 300 nm, as given by *Lean* [1987], although some structure can be seen at strong features, such as the Ca II H and K lines at 393 and 397 nm.

The NOAA 9 scale factors shown in Figure 4 reproduce the wavelength dependence of the Nimbus 7 scale factors very well in a broad sense and also at shorter length scales down to less than 5 nm. However, the magnitude of the NOAA 9 scale factors is approximately 20–30% lower than

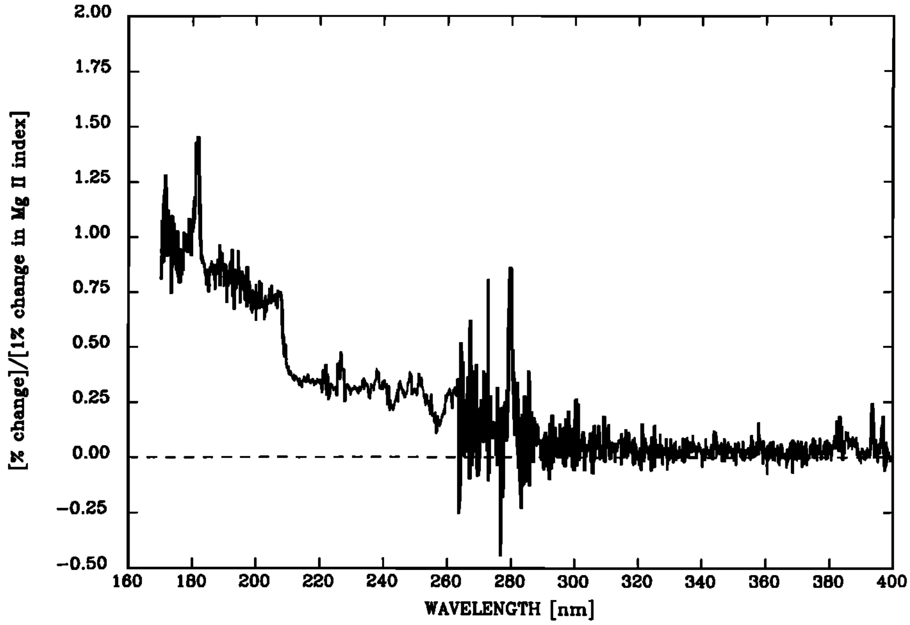

Fig. 4. NOAA 9 scale factors for solar variability derived from seven strong solar rotations during 1989–1990.

the Nimbus 7 scale factors at all wavelengths below 300 nm, where significant solar variability is expected. This difference in magnitude is caused by the large fluctuations in the derived irradiances at the Mg II index wing wavelengths. Over a long period of time, random variations in the Mg II index value caused by fluctuations in the wing irradiances will produce approximately equal numbers of values which are either higher or lower than would be expected for the derived Mg II core irradiance. However, in the process of selecting Mg II index rotational modulation maxima and minima for the derivation of scale factors, wing irradiance fluctuations which drive the Mg II index value in the direction of the local extremum are likely to be preferentially selected. As a result, the magnitude of the Mg II index rotational modulation strength will tend to be greater than the rotational strength of the Mg II core irradiance values. For Nimbus 7, where the SBUV instrument design avoided the gain range problem of the SBUV 2 instrument, the average of the scale factors for the three Mg II core wavelengths is 1.09, which is consistent with Mg II wing wavelength scale factors between 0.08 and 0.11 and the requirement that the Mg II index scale factor equal 1.0. Since the average of the derived Mg II core scale factors for NOAA 9 is 0.84, a problem clearly exists.

Because the Mg II index variations caused by wing irradiance fluctuations are a common element in all scale factor derivations, it should be possible to make a simple correction that will improve the agreement with the Nimbus 7 scale factors. We have chosen to normalize the average of the NOAA 9 scale factors derived for the three Mg II core wavelengths to the average of the three Mg II core scale factors for Nimbus 7. The original set of NOAA 9 scale factors is then multiplied by the normalization factor to generate a new data set. In Figure 5 the normalized NOAA 9 scale factors are shown along with the Nimbus 7 scale factors, with a 5-point binomial average in wavelength applied to smooth the data. The differences between the two data sets at wavelengths below 260 nm have been reduced to 5–10%. The only physical constraint on the normalized NOAA 9 scale factors is the requirement of agreement with the Nimbus 7 scale factors at the Mg II core wavelengths. Most small scale (1–10 nm in width) features in the Nimbus 7 scale factors are reproduced well in the NOAA 9 scale factors, supporting the argument that the problem with noise in the wing wavelength irradiances affects only the magnitude of the derived scale factors. Table 3 presents the normalized and smoothed scale factors at selected wavelengths, where a cubic spline has been used to reduce the NOAA 9 scale factors data set to 0.2 nm resolution. The quoted uncertainties represent the standard deviation derived for each scale factor value. The consistency of these results with the Nimbus 7 results at all wavelengths outside the 265- to 290-nm region implies that the Mg II index scale factors accurately represent the wavelength dependence of solar ultraviolet variability on a rotational time scale. *HS* and *Schlesinger and Heath* [1988] have used the Mg II index and scale factors to consider solar irradiance changes on time scales of a solar cycle, with the assumption that the wavelength dependence of the irradiance variations derived from rotational modulations is the same on both short-term and long-term time scales. The existence of a "network" component of long-term solar ultraviolet variability, which complements the baseline "quiet Sun" value and the short-term variations caused by the growth and decay of active regions, has been discussed extensively [*Lean*, 1987]. However, there is no conclusive evidence suggesting that the wavelength dependence of irradiance variations due to such a component differs significantly from the wavelength dependence of rotational modulation variations. If we use the normalized NOAA 9 scale factors shown in Figure 5 to estimate long-term solar irradiance changes, then based on an increase of 9% in the 27-day averaged NOAA 9 Mg II index during the rise of solar cycle 22 from September 1986 to early 1989, the corresponding irradiance changes are approximately 8.6 ± 1.8% at 205 nm, 3.5 ± 0.8% at 250 nm,

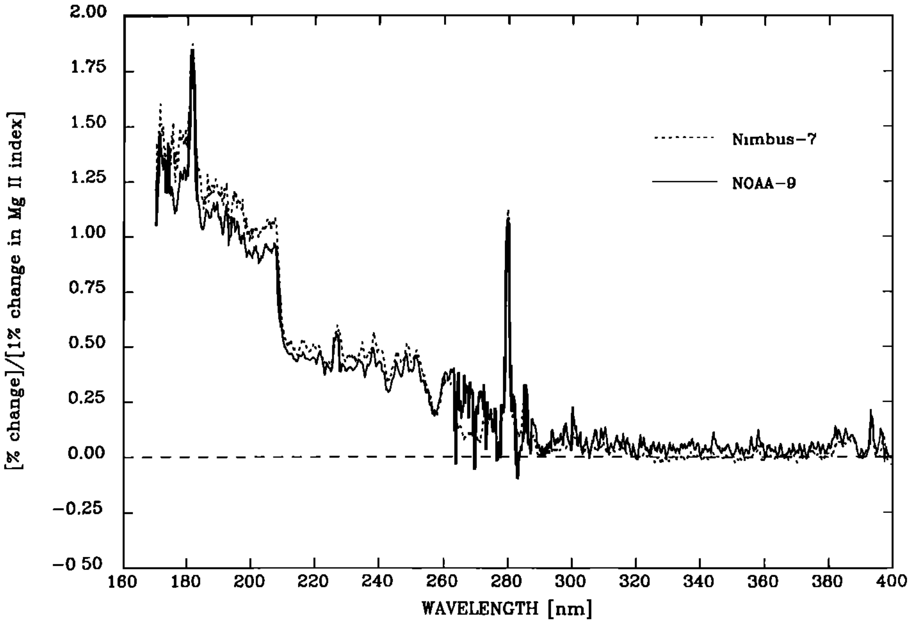

Fig. 5. NOAA 9 scale factors normalized as discussed in the text (solid line). A 5-point binomial average over wavelength has been applied to the NOAA 9 scale factors for clarity of presentation. All other parameters are identical to Figure 4. Also shown are the Nimbus 7 scale factors as derived by *HS* (dashed line).

and zero longward of 300 nm within the uncertainties of the measurements.

CONCLUSION

The Mg II core to wing index can be used as an indicator of solar ultraviolet activity on both rotational and solar cycle time scales. NOAA 9 Mg II index results show an increase of 9% during the rise of solar cycle 22 between September 1986 and summer 1989, in agreement with increases in solar activity observed by other indicators such as sunspot number and 10.7 cm flux. Coincident with the rise in mean solar activity the rotational modulation amplitude increased from approximately 1–2% in 1985–1986 to about 4–7% in 1989–1990. The Mg II index can also be used to estimate solar variability at other UV wavelengths by deriving multiplicative factors to scale the observed Mg II variations to those wavelengths. Scale factor results derived for NOAA 9 SBUV 2 show a wavelength dependence in good agreement with the Nimbus 7 SBUV scale factor results and agree very well in magnitude when a correction is made for noise in the wing wavelengths of the NOAA 9 Mg II index. The Mg II index scale factors provide a useful method for estimating solar UV variability during periods when no other measurements are available. The NOAA 9 SBUV 2 Mg II index values and scale factors used in this paper are available on diskette, along with a brief description of the solar irradiance data set from which the Mg II index and scale factors were derived. For further information, please contact R. P. Cebula. We are presently extending this analysis to solar irradiance data from NOAA 11 SBUV 2 instrument and will then produce an integrated Mg II index covering the declining portion of solar cycles 21 and 22 [*DeLand and Cebula*, 1992].

TABLE 3. Selected NOAA 9 Scale Factors

Wavelength, nm	Line	Scale Factor
181.4	Si II	1.82 ± 0.45
205.0	Al edge	0.96 ± 0.21
250.0		0.39 ± 0.08
280.0	Mg II	1.05 ± 0.19
285.2	Mg I	0.24 ± 0.16
300.0		0.10 ± 0.22
350.0		0.01 ± 0.09
358.2	Fe I	0.11 ± 0.12
393.4	Ca II K	0.19 ± 0.15
396.8	Ca II H	0.10 ± 0.14

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